This alternative is consistent with the goal of increasing hard-target capability, though it would not result in as large an increase as under the Administration's plan. Canceling backfits would reduce costs but would yield only small savings over the next few years. If higher near-term savings are to be achieved, the Trident II program would have to be delayed.

ALTERNATIVE 2: REDUCE AND DELAY PROCUREMENT OF TRIDENT II MISSILES

As in Alternative 1, this option would cancel the plan to backfit the first eight Trident submarines with Trident II missiles. In addition, Trident I missiles would be deployed on four more Trident submarines (the ninth through the twelfth), thereby maximizing the use of existing Trident I missiles and requiring procurement of only 516 Trident II missiles-328 fewer than in the Administration's plan. Deploying Trident I missiles aboard the ninth through twelfth Trident submarines would also allow a three-year delay in the procurement of Trident II missiles, resulting in larger near-term savings than with the first alternative. In the long term, however, this option would cost slightly more than the first alternative as a result of increased research and development costs for the Trident II missile.

Effect on Capability

This option would reduce the number of U.S. prompt hard-target warheads by the year 2000 by about 40 percent, and would have a significant effect on U.S. ability to retaliate with SLBMs against a large target set. It would have virtually no effect, however, on U.S. ability to retaliate with SLBMs against a small target set.

By deploying Trident II missiles aboard only eight submarines rather than 20, as in the Administration's plan, this option would greatly diminish total growth in the number of hard-target warheads. In the year 2000, the United States would have about 3,920 hard-target warheads rather than 6,800 as under the Administration's plan. 7/ Of this reduction of 2,880 hard-target warheads, approximately 1,150 would be Class 1 and 1,730 would be Class 3; as under Alternative 1, the number of Class 2 warheads would not change (see Figure 12).

^{7.} The number of warheads would not change, though, until 1990 when, under the Administration's plan, the ninth Trident submarine would enter service.

The decrease in the number of U.S. prompt hard-target warheads under this option would affect their performance against target sets of hard-ened facilities. If both ICBMs and SLBMs were available to attack a large target set of 2,000-psi facilities, performance would decrease from the destruction of 90 percent of the targets under the Administration's plan to 84 percent (see Figure 13). If only SLBMs were available, the percentage of targets destroyed would decrease from 85 percent to 63 percent (see Figure 14). Against a smaller target set, reflecting the mission of conducting a limited retaliatory strike, the performance of SLBMs would decrease from destroying 93 percent of the targets to 89 percent (see Figure 15).

Effect on Costs

Over the life of the Trident II program, this alternative would save \$2.9 billion in budget authority. Savings in 1987 would amount to \$0.4 billion and would total \$1.4 billion over the next five years. In the near term, these savings would be greater than under Alternative 1 because procurement of the Trident II would be deferred until 1990. Long-term savings, however, would be lower because research and development costs would increase for the Trident II missile.

The major savings in this alternative come from canceling the backfit of the first eight Trident submarines and putting Trident I missiles on the ninth through the twelfth submarines, which would lower the number of Trident II missiles required by 328. 8/ These savings would not be offset by the purchase of more Trident I missiles, because missiles in storage and on retiring submarines would be used. To provide enough Trident I missiles to fill the additional four Trident submarines, five Poseidon submarines carrying the Trident I missile would have to be retired approximately three years earlier than planned. To minimize the reduction in capability caused by these early retirements, the service of Poseidon submarines carrying the Poseidon missile, which otherwise would have been retired, could be extended. 9/

^{8.} Since in some years a maximum of eight submarines would be deployed with Trident II missiles under this alternative rather than 19 submarines as under the Administration's plan (of the 20 Trident submarines, one would always be undergoing an overhaul), it would be necessary to procure 11 fewer shiploads of missiles. In addition, the FOT program would be delayed by three years, saving 36 missiles, and the DASO program would be reduced by 28 missiles. Therefore, Trident II procurement would be reduced by 328 missiles ((11 x 24) + 36 + 28 = 328 missiles).

^{9.} The extended service of the Poseidon submarines would not include deploying them beyond the period that they can operate without a major overhaul.

Although this alternative would not require procurement of additional Trident I missiles, it would have significant costs that partially offset savings. Most important, funding for the Trident II program would have to be continued to keep a design and manufacturing team together until procurement begins in 1990. That would add about \$3.5 billion to the cost of the Trident II missile program. In addition, the Navy either would have to modify facilities at Bangor, Washington, to handle 12 rather than 10 Trident submarines carrying Trident I missiles, or it would have to modify the base at Kings Bay to handle Trident I missiles. The Navy also would have to reconfigure the ninth through twelfth Trident submarines, which are currently under construction, with equipment designed for the Trident I missile. These changes would include a smaller launch tube, a different gas ejection system, and the modification or replacement of electrical subsystems that interface with the missile, such as the fire control system and the navigation system. 10/ Although a detailed engineering study would be required to refine modification plans and cost estimates, the Navy currently estimates that the changes will cost roughly \$250 million for each of the four submarines. 11/

This alternative would employ the existing inventory of Trident I missiles more efficiently than the previous alternative by increasing and prolonging deployments, but would decrease the efficiency of the Trident II program because the delay would add to research costs. The latter effect outweighs the former, resulting in lower long-term savings than under Alternative 1.

Other Effects

By deploying four more Trident submarines with Trident I missiles and delaying Trident II procurement, this option would allow the Congress more time to assess the Trident II program in light of fiscal constraints and questions about the need for hard-target capability. The time required to procure and install the equipment to deploy the Trident I missile on those four

^{10.} Since the Trident I missile is much lighter than the Trident II missile, a different gas ejection system is required to propel it to the surface at the proper speed.

^{11.} The ninth submarine is almost ready to be launched. Some weapon subsystems, however, will be fitted into the submarine after it is in the water. The subsequent submarines are less complete but are receiving more equipment at earlier stages in construction. Therefore, a different engineering plan would have to be developed for each submarine. It is not evident at this point how much less expensive it would be to convert the twelfth submarine than to convert the ninth. Consequently, the full conversion price supplied by the Navy has been applied to all four submarines.

additional Trident submarines, however, would probably delay deployment of each submarine by up to two years. These delays would be compensated for by keeping the Poseidon ships with Trident I missiles at sea longer, resulting in little impact on the capability of the ballistic missile fleet.

As in the previous alternative, the Trident I FOT flight-test program would continue through the year 2012 to support extended deployment of Trident I missiles. Since fewer missiles would be available for testing as a result of the larger number that are deployed, however, the number of flight tests would have to be limited to six per year. This lower level of testing would meet the minimum requirement established by the Joint Chiefs of Staff and would have little effect on estimates of the missile's accuracy and reliability. It would have some effect, however, on the time required to detect and correct emerging problems. 12/ Also, most DASO flights for the Trident I would have to come at the expense of the FOT program.

Limits on Trident I testing could, of course, be avoided if the Administration purchased more Trident I missiles. The production line for these missiles has been closed, however, and--as the next alternative makes clear --reopening the line would be too expensive for purchasing test missiles alone.

ALTERNATIVE 3: CANCEL THE TRIDENT II PROGRAM

Canceling the Trident II program would mean that no further development or production would be funded beyond 1986. The Trident I production line would be reopened in 1990 to provide enough Trident I missiles to fill 20 Trident submarines and to conduct a flight-test program at the level cur-

^{12.} If an estimate of missile reliability were based on test results from a single year, there would be a high expected error in the estimate because of the small size of the data base. Therefore, the Navy estimates reliability on the basis of all relevant flight-test data. With that methodology, decreasing the number of annual flight tests from eight (as in Alternative 1) to six would increase the expected error in the estimate of reliability by less than one percentage point. The decrease from eight tests per year to six tests per year would increase the expected error in the estimate of CEP employed in the Strategic Integrated Operational Plan (SIOP) by less than three feet. That change is not significant enough to affect either the missions assigned to the missile or calculations of expected damage. The average number of months required to detect an emerging problem would increase from a level of 4 to 15 months in Alternative 1 (the range reflects differing assumptions about the value of information from inspections and component tests) to 5 to 20 months under Alternative 2. See Congressional Budget Office, "Trident II Missile Test Program" (Staff Working Paper, February 1986).

rently planned for the Trident II missile. An additional 395 Trident I missiles would have to be procured.

Effect on Capability

By canceling the Trident II missile program and thus eliminating the deployment of hard-target warheads on submarines, this option would substantially reduce U.S. ability to conduct retaliatory strikes on either large or small sets of time-urgent hardened targets in the Soviet Union.

Under this alternative, the only growth in the U.S. inventory of prompt hard-target warheads would result from the deployment of 500 warheads on 50 MX missiles. Thus, by the year 2000, the United States would have only 2,000 prompt hard-target warheads (1,500 Minuteman III warheads in addition to 500 MX warheads) instead of the 6,800 warheads under the Administration's plan.

The decrease in the number of U.S. prompt hard-target warheads under this option would have a larger effect on performance against target sets of hardened facilities than under the other two alternatives. If U.S. ICBMs and SLBMs were both available to attack a set of 2,000 facilities hardened to 2,000 psi, performance would decrease from the destruction of 90 percent of the targets under the Administration's plan to 69 percent (see Figure 13). If only SLBMs were available, 32 percent of the targets would be destroyed, compared with 84 percent under the Administration's plan (see Figure 14). If the performance of only U.S. SLBMs is weighed against a smaller target set, performance would decrease from 93 percent under the Administration's plan to 33 percent (see Figure 15). 13/

Proponents of hard-target capability might view this alternative as diminishing U.S. ability to deter a limited strike or, should nuclear war begin, to conduct a limited strike best suited to U.S. political and military objectives. To opponents of increased hard-target capability, however, this decrease would neither weaken U.S. deterrence nor affect limited retaliatory options that are compatible with the objective of controlling escalation. Furthermore, opponents would argue, this decrease in capability would lower the probability that a crisis would escalate to nuclear war.

^{13.} If the United States proceeds to procure and deploy small mobile ICBMs with hard-target capability, these ICBMs would considerably improve U.S. ability to conduct retaliatory strikes against time-urgent hardened targets under this option.

Effect on Cost

This alternative would save between \$9.6 billion and \$11.3 billion in budget authority, depending on the cost of reopening the Trident I production line. On the basis of the lower figure, savings would amount to \$0.4 billion in 1987 and would total \$2.0 billion over the next five years. On the basis of the higher savings figure, an additional \$1.7 billion in savings would accrue between 1987 and 1990.

As in Alternative 2, these savings are the net result of decreases and partially offsetting increases in costs. On the one hand, this alternative would generate significant savings by canceling the production of 844 Trident II missiles, the Trident II missile test program, and the modification of the first eight Trident submarines to enable them to carry Trident II missiles. On the other hand, increased costs described in Alternative 2 would be incurred. The Navy would have to modify the Trident submarines currently under construction to carry the Trident I missile rather than the Trident II. 14/ Also, a delay of up to two years would occur in deploying those submarines and would have to be compensated for by extending the deployment of Poseidon submarines.

More important, and unique to this option, is the reopening of the Trident I missile line. Reopening the line would require requalifying contractors, refurbishing and replacing tooling, redesigning parts for which the original materials are unavailable, and testing the new parts to ensure that the performance characteristics match those of the original parts. In addition, the submarine port at Kings Bay, Georgia, would have to be modified to handle the Trident I rather than the Trident II. These activities would cost between \$3.5 billion and \$5.2 billion. Finally, procuring the additional 395 Trident I missiles would cost about \$11 billion.

Other Effects

This alternative, in contrast to the previous one, could maintain the test program for the Trident I missile at levels currently planned for the Trident II because, with a new production line open, additional Trident I mis-

^{14.} Whereas in Alternative 1 (which called for the deployment of 12 submarines with Trident I missiles) it would be necessary to modify four of the five Trident submarines under construction, in this alternative all five (the ninth through the thirteenth) would have to be modified. The fourteenth Trident submarine, for which the Administration has requested funding in fiscal year 1987, would be built from the beginning to carry the Trident I missile.

siles could be purchased. Specifically, the FOT program would be set at 12 missiles per year for 1990 through 2012. The DASO program would be increased by 52 missiles so that every new or overhauled Trident submarine would be able to launch a missile before becoming operational. Also, the Fleet Return Evaluation Program (FREP) would be maintained at 30 missiles, the level currently planned for the Trident II program. 15/

Finally, if the Trident II program were canceled, the United States would not be able to provide Trident II missiles to the United Kingdom, which is beginning construction of the first of four submarines designed to accommodate 16 Trident II missiles each. Consequently, the United Kingdom would have to modify plans for the submarines so that they would carry Trident I rather than Trident II missiles.

^{15.} The FREP program provides a reserve so that enough missiles will be available for scheduled deployments even though some missiles are being transported, dismantled, inspected, or reassembled. Missiles are likely to be in one of those conditions as a result of two procedures. First, the Navy regularly removes a deployed missile from a submarine to examine it for signs of deterioration. These missiles--called Service Life Evaluation (SLE) missiles--are not destroyed. Following ground-based inspections and tests, the components reenter the parts inventory and are incorporated into new or refurbished missiles as required. Second, when a submarine undergoes a major overhaul, all the missiles on that submarine are dismantled. As with SLE missiles, the components reenter the parts inventory following inspection and, if needed, repair.

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METHOD USED TO CALCULATE SSKP

The probability that a warhead will destroy a target is a function of reliability (the probability that the warhead will arrive at the target and detonate) and the Single Shot Kill Probability (SSKP--the probability that the arriving warhead will destroy the target). The SSKP of a warhead depends on the hardness of a target and on the warhead's yield and accuracy. Yield affects the SSKP because a weapon of higher yield produces, at any given radius from the blast, a higher peak overpressure (pressure above standard atmospheric pressure) and a longer period of high overpressures. Both a higher peak overpressure and a longer period of high overpressures increase the probability that a structure will suffer major structural damage from a blast. Better accuracy reduces the distance between the target and the blast.

The method used in this study to calculate the SSKP was developed by the Defense Nuclear Agency (DNA). That method employs an index of target hardness called a vulnerability or "V" number. The index is pegged to a reference yield of 20 kilotons (kt), which is a simple way to make the duration of the period of high overpressures a function of the peak overpressure generated by a blast. Thus, each target is given a V number based on the level of peak overpressure (generated by a 20-kt blast) at which the target has a 50 percent probability of suffering major structural damage.

Public statements by the Department of Defense on the hardness of targets, however, are given in terms of pounds per square inch (psi) of peak overpressure rather than in terms of a V number. The hardness (H) in pounds per square inch can be converted to a V number with the following formula: 1/

$$V = (5.485 \times ln(H)) + 4.08$$

(continued)

^{1.} This formula can be derived by inserting yield (Y=1,000 kt) and the k-factor (k=7) into the following set of formulas:

¹⁾ a = 1 - .1k

²⁾ $b = .1k \times (20/Y)^{1/3}$

This formula is based on the assumption that although the V number uses a reference yield of 20 kt, a reference yield of one megaton has been used for estimates of the hardness of Soviet silos measured in pounds per square inch. 2/ The formula is also based on the assumption that structures such as Soviet silos have a sensitivity to the duration of the period of high overpressures, as measured by an index called the "k-factor," of 7. 3/ A formula based on alternative assumptions can be derived from the set of formulas given in footnote 1. With the appropriate V number and k-factor, the probability that a weapon would destroy a target (that is, cause major structural damage) was calculated by using Continuous Read Only Memory (CROM) software developed by DNA. 4/ The CROM software was used in this study because it compensates for the duration of the period of high overpressure, allows calculations at high levels of target hardness such as 5,000 psi, and can be programmed to perform multiple calculations. Comparable results can also be obtained by using a circular slide rule (the "Damage Prediction Rule") developed and distributed by DNA.

There are several alternatives to the DNA CROM software and slide rule for calculating SSKP values. A circular slide rule is manufactured by the Rand Corporation titled the "Bomb Damage Effect Computer." It can calculate SSKP values for targets up to a hardness of 1,000 psi. Two formulas also have been developed to calculate SSKP values. 5/ In these formu-

See Maurice Mizrahi, "Appendix A: Hard-Target-Kill Methodology (Unclassified)," *Mobile Missile Mix* (Center for Naval Analysis, Study 1170, vol. 3, April 1982).

- 2. Information provided by the Defense Nuclear Agency.
- 3. The k-factor for hardened underground structures such as Soviet ICBM silos normally is between 7 and 8 (Defense Nuclear Agency).
- 4. Defense Nuclear Agency, Nuclear Weapons Targeting, AP-550, CROM Al, Report Number HTI-R-79-110, June 1, 1979 (Unclassified).
- 5. Both formulas are presented in detail in Lynn Davis and Warner Schilling, "All You Ever Wanted To Know About MIRV and ICBM Calculations But Were Not Cleared To Ask," Journal of Conflict Resolution, vol. XVII, no. 2 (June 1973). Given the assumptions made in this study (k-factor of 7 and reference yield of one megaton), these formulas give comparable results to the CROM Al software when warhead yield is 100 kt. At significantly lower or higher yields, results can diverge substantially.

^{1. (}continued)

³⁾ $R = a + (b^2/2) + .5((2a+b^2)^2-4a^2).5$

⁴⁾ $V' = (5.485 \times \ln (H)) - .63$

⁵⁾ $V = V' - (5.485 \times ln(R))$

las, "Y" is the yield measured in megatons; "H" is the hardness of the target measured in pounds per square inch (psi); and "CEP" is the accuracy measured in nautical miles by the Circular Error Probable--the radius of a circle around a target such that there is a 50 percent probability that the warhead aimed at the target will detonate within or above the circle.

1) SSKP = 1-.5^A where A =
$$\frac{6Y^{2/3}}{H^{2/3}CEP^2}$$

2) SSKP = 1-.5^A where A =
$$\frac{8.41Y^{2/3}}{H^{.7}CEP^2}$$

The SSKP calculated using these different approaches can, under some assumptions, vary by 10 percent to 15 percent. Such variations should not be a major cause for concern, however, when placed in the context of uncertainty about other assumptions including weapon reliability, the yield and accuracy of warheads, the overpressure required to crush or deform particular structures, and the probability that a facility would be disabled by effects other than major structural damage.

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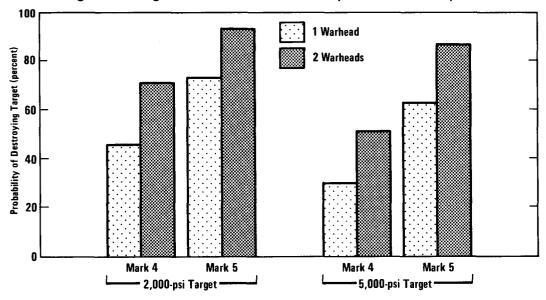
THE CHOICE OF TRIDENT II WARHEADS

This study assumes that 50 percent of the Trident II missiles would be deployed with the Mark 4 warhead and 50 percent with the Mark 5. This ratio affects the capability of the Trident II missile force. Although the Trident II can carry fewer Mark 5 warheads (six to nine) than Mark 4 warheads (11 to 13), the yield of the Mark 5 (400-500 kt) is higher than the yield of the Mark 4 (100 kt). The higher yield of the Mark 5 gives it a higher Single Shot Kill Probability (SSKP--the probability that an arriving warhead will destroy a target) than the Mark 4. One Mark 5 warhead, for example, has a higher probability than two Mark 4 warheads of destroying a target hardened to 2,000 or 5,000 pounds per square inch (psi) (see Figure B-1).

Figure B-1.

Effectiveness of Mark 4 and Mark 5 Warheads on the Trident II

Missile Against Targets Hardened to 2,000 psi and 5,000 psi



SOURCE: Congressional Budget Office.

NOTE: Effectiveness is measured here by the probability that either one or two warheads will destroy a hardened target. That probability, known as the probability of kill (PK), is based on the Single Shot Kill Probability (SSKP) for each warhead type against a target of specified hardness and on the reliability (R) of 80 percent. The calculations employ the following equation, in which "N" is the number of warheads directed at the target:

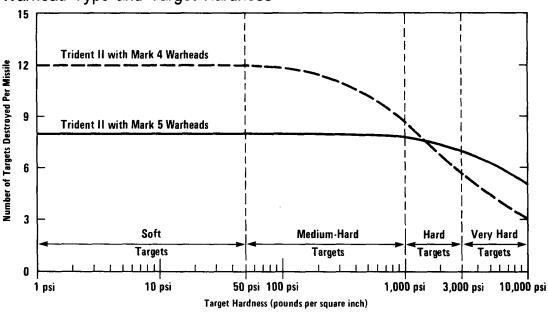
$$PK = 1 - [1 - (SSKP \times R)]^{N}$$

Therefore, there is a trade-off between the number of warheads and the capability of the individual warheads. Against "soft" targets hardened to less than 50 psi--a situation in which the difference in yield between the Mark 4 and Mark 5 warheads has little effect on the SSKP--the Trident II missile with Mark 4 warheads could attack and destroy more soft targets than with Mark 5 warheads (see Figure B-2). Against targets hardened to greater than about 1,600 psi, however, the Trident II missile with Mark 5 warheads would be more effective. Because of the higher SSKP of the Mark 5 warhead against harder targets, a Trident II missile would destroy more targets with fewer Mark 5 warheads than with a larger number of Mark 4 warheads (see Figure B-2).

For attacking targets hardened to an intermediate range of between 50 psi and 1,600 psi, however, the relative effectiveness of Mark 4 and Mark 5 warheads is less clear. The Trident II with Mark 4 warheads is more effective if each warhead is directed against a separate target. But, if some Mark 4 warheads are not used because there are more warheads

Figure B-2.

Capability of a Single Trident II Missile as a Function of Warhead Type and Target Hardness



 ${\bf SOURCE:\ Congressional\ Budget\ Office.}$

NOTE: The Trident II could carry 11 to 13 Mark 4 warheads or 6 to 9 Mark 5 warheads. For the purpose of illustration, it is assumed that the missile would carry 12 Mark 4 warheads or 8 Mark 5 warheads.

than targets within the footprint of the missile (the area over which a single missile can distribute its warheads), then the Trident II equipped with Mark 5 warheads might be more effective.

The relationship between the number of warheads and their yield has implications for both proponents and opponents of expanded hard-target capability. Proponents would want to ensure that the percentage of Trident II missiles equipped with Mark 4 and Mark 5 warheads would result in the maximum capability and flexibility against the set of hardened targets in the Soviet Union. The optimal mix of warheads is difficult to determine, however, without detailed analysis of the U.S. Strategic Integrated Operational Plan (SIOP)--the nation's blueprint for conducting strategic nuclear war. Since this plan is classified, determining the optimal mix probably must be left to the Joint Strategic Target Planning Staff and the Department of Defense.

For opponents of expanded hard-target capability, the issue is the degree to which selecting one warhead rather than the other might minimize the destabilizing effects of deploying the Trident II missile. To achieve this objective, the case is strongest for deploying only the Mark 4 warhead. Whether only the Mark 4 or only the Mark 5 were deployed, the United States would have enough prompt hard-target warheads on SLBMs to employ at least two such warheads against as many as 1,800 to 1,900 of the most important Soviet installations. Therefore, the most relevant factor is not the number of Mark 4 and Mark 5 warheads that the Trident II missiles can carry, but the yield of the warheads. From the perspective of opponents of expanded hard-target capability, the higher yield of the Mark 5 and corresponding greater vulnerability of certain Soviet facilities increase the probability that a crisis would escalate to nuclear war (see Chapter II).

The objectives of opponents of expanded hard-target capability might also be met by deploying a warhead on the Trident II missile that has a lower yield than either the Mark 4 or Mark 5 warhead. For example, a 25-kt warhead on the Trident II would have the same capability against hardened targets as the Mark 4 warhead on the Trident I but would reduce collateral damage (unintended damage to facilities and urban areas located near the intended target). Moreover, the lower weight of the smaller warheads would enable the Trident II either to have greater range or to have greater payload that could be devoted to "penetration aids"--devices that would ensure that the Trident II would remain effective despite improvements in Soviet anti-ballistic missile systems.

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APPENDIX C

PERFORMANCE OF U.S. BALLISTIC

MISSILES AGAINST TARGET SETS

HARDENED TO 5,000 PSI

In the text of this report, the performance of U.S. ICBMs and SLBMs was evaluated against target sets hardened to both 2,000 and 5,000 pounds per square inch (psi). To simplify presentation and to facilitate comparison of the performance of U.S. ICBMs and SLBMs under the Administration's plan and alternatives to that plan, however, Figures 13 through 15 in the text presented the performance of U.S. ballistic missiles only against target sets hardened to 2,000 psi. Figures C-1, C-2, and C-3 (overleaf) are the same figures except that they present performance against target sets hardened to 5,000 psi.

Figure C-1.

Administration's Plan and Alternatives:
Performance of U.S.
ICBMs and SLBMs
Against a Large Target
Set, Fiscal Years
1985-2000

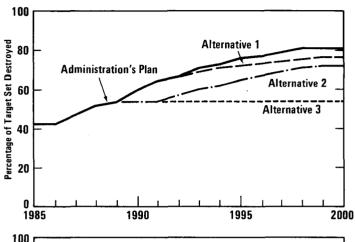


Figure C-2.

Administration's Plan and Alternatives:
Performance of U.S.
SLBMs Against a Large Target Set, Fiscal Years 1985-2000

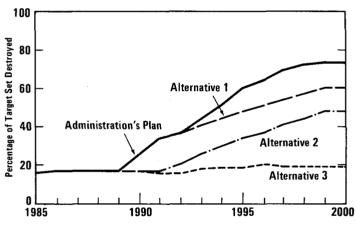
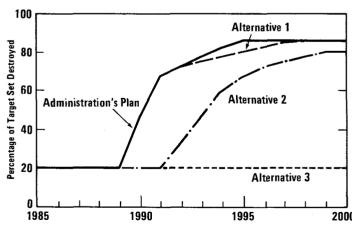


Figure C-3.

Administration's Plan and Alternatives: Performance of U.S. SLBMs Against a Small Target Set, Fiscal Years 1985-2000



SOURCE: Congressional Budget Office.

NOTES: A large target set (Figures C-1 and C-2) is 2,000 facilities; a small target set (Figure C-3) is 500 facilities. All three figures illustrate the performance of ballistic missiles against target sets hardened to 5,000 psi. The calculations are based on the assumptions that no more than two warheads are allocated against any one target and that the reliability of SLBMs is 80 percent. U.S. warheads are allocated to maximize the percentage of targets destroyed. Alternative 1 = Cancel Backfits; Alternative 2 = Delay Procurement of Trident II Missiles; Alternative 3 = Cancel Trident II Program.